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USE OF RUBBER DAMS FOR FLOOD MITIGATION IN HONG KONG[A]

Discussion by Hubert CHANSON[b]

The discusser congratulates the author for his interesting paper on rubber dams. For completeness the discusser wishes to add further information on the Australian experience with rubber dams and possible causes of rubber dam damage.

Australian experience with rubber dams

Rubber dams (i.e. inflatable flexible membrane dams) have been in use for over thirty years in Australia (table 3). After an initial interest for rubber dams in the late sixties, these structures went out of favour following failures (e.g. Koombooloomba dam, SHEPERD et al. 1969). Recently the interest for rubber dams has increased again as these structures become more reliable.

The hydraulic design of overflow above rubber dams is presently under investigation in Brisbane (University of Queensland, Department of Natural Resources). It is hoped that new results will be available in a near future.

It is worth noting that the list of rubber dam manufacturer (in use in Australia) includes a local manufacturer : Queensland Rubber Co. (Brisbane, Australia).

Damage to rubber membranes

The author listed some potential causes for damage including vandalism. For completeness the discusser would like to describe other causes of damage : i.e., hydrodynamic instabilities and debris passage.

During the overflow of deflated rubber dams, the flexible membrane must lie flat on the floor to minimise flow disturbances and head losses. Anchors and casing must be streamlined with the floor, using a recess in the concrete floor. These dispositions minimise the floor discontinuity (protuberance or gap) caused by the rubber bag and reduce the vortex shedding effects.

For inflated rubber dams, the overflowing nappe adheres to the downstream rubber wall and the adherence of the nappe might lead to flow instability at the base of the nappe (i.e. next to the separation position), pressure fluctuations on the downstream face of the dam and vibrations of the flexible membrane. In laboratory tests, OGIHARA and MARAMATSU (1985) recorded accelerations of the membrane (in a direction normal to the skin) of up to 0.12*g for H/D less than 1.8, where g is the gravity acceleration, D is the rubber dam height and H is the upstream total head.

Nappe adherence vibrations can be eliminated by ventilating the underside of the nappe and by deflecting the nappe off the rubber dam wall (fig. 10). In practice the later method is nowadays commonly used. The deflector is designed to project the nappe away from the membrane and to prevent the nappe re-attachment on the membrane. The optimum characteristics of deflector were investigated by the discusser (CHANSON 1996).

During a small overflow event above an inflated rubber dam equipped with a deflector, an air cavity forms between the membrane and the thin nappe of water. Free-surface undulations and fluttering instabilities might occur if the air cavity is not or poorly ventilated (i.e. Kelvin-Helmholtz instability). Kelvin-Helmholtz instabilities can be controlled or

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prevented by two means : nappe ventilation and splitters[1]. Usually splitters are installed along the deflector at regular intervals to divide the nappe in several narrower nappes, creating numerous gaps in the nappe allowing for the passage of air.

Another form of hydrodynamic instability is the presence of near-critical flows (i.e. undular flows) in the vicinity of both inflated and deflated membrane dams. Undular flows are characterised by fluctuating bottom pressures and shear stresses. In some particular cases, separation and regions of very-low pressure might take place and this might lead to uplift effort on the membrane. Such fluctuating loads are not acceptable on a flexible membrane. CHERVET (1984) described one prototype failure case caused by undular flow. CHANSON (1995,1996) provided several criteria for undular flow situations.

Damage to rubber dams may be caused also by debris : i.e., recurrent abrasion and debris impacts. Abrasion may be caused by the overflow of quartz sediment, ice, branch. A protective casing or steel gate can be considered to reduce or prevent membrane abrasion (e.g. Omata weir, Japan). Debris impact is not often taken into account and the impact process is still poorly understood. In one case (Ngalimbiu bridge, Solomon islands), substantial damage to concrete bridge piers was reported with plastic hinges in the pier portals. The equivalent static force at headstock level was estimated in excess of 3,000 kN, and it is believed that debris impacts contributed to the bridge failure (BOYCE 1987) ! Altogether the impact of debris (branch, tree, log, ice) must be avoided at any cost because of the risk of puncture. A hard cover (e.g. steel gate) might be required in case of potential debris impacts. Alternatively rigid dams or gates must be selected in place of rubber dams.

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NOTATION

D	=	rubber dam height (m);
H	=	head above dam crest (m);
H_{infl}	=	maximum head (m) above inflated rubber dam crest (m)

[1]also called spoilers, longitudinal fins, dividing walls, cutwaters.

L = rubber dam length (m);

Table 3 - Examples of rubber dams installed in Australia

Year (1)	Site (2)	Characteristics (3)	Manufacturer (4)	Remarks (5)
1965	Koombooloomba dam, Queensland	$L = 1 \times 60$ m $D = 1.22$ & 1.5 m $H_{infl} = 0.91$ m Water filled	Fabridam-Firestone	Rubber membrane without deflector. Placed on an ogee crest. Automatic deflation system (mechanical). Design overflow : 142 m^3/s (inflated), 2,120 m^3/s (deflated).
1967	Proston weir, Queensland	$L = 1 \times 51$ m $D = 1.5$ m $H_{infl} = 1.4$ m Water filled	Fabridam-Firestone	Rubber membrane without deflector. Automatic deflation system (mechanical).
1983	Val Bird weir, North Queensland	$L = 2 \times 82$ m $D = 1.9$ m $H_{infl} = 0.5$ m Water filled	Fabridam-Firestone	Automatic deflation system (mechanical : siphon).
1996	Lyell dam, New South Wales	$L = 2 \times 40$ m $D = 3.5$ m $H_{infl} = 1.4$ m Air filled	Bridgestone	Rubber membrane equipped with a deflector. Automatic deflation systems.
1997	Dumbleton weir, Central Queensland	$L = 2 \times 75$ m $D = 2$ m $H_{infl} = 0.7$ m Air filled	Queensland Rubber Co.	Rubber membrane equipped with a deflector. Automatic deflation systems (electrical and mechanical).

Note : D : rubber dam height (fully-inflated); H_{infl} : maximum head above inflated rubber dam crest; L : length of membrane.

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Fig. 10 - Sketch of overflow above a rubber dam equipped with a deflector (i.e. fin)